ARPA Network Information Center
Stanford Research Institute
Menlo Park, California 94025
NIC #14527
Packet Radio Temporary Note 29

L. Schaefer
Stanford Research Institute
February 23, 1973

FACSIMILE DATA FORMAT

1. Introduction

The purpose of this note is to discuss the data format of modern facsimile machines, as they are known to the author. A review of the data format of traditional facsimile machines is given first to provide a basis of comparison.

2. Traditional Facsimile Machines

The traditional facsimile machine described here is primarily designed to transmit the information contained on an 8-1/2 by 11 inch page over a telephone line. Subjectively it has been determined that approximately 100 scan lines per inch provides adequate quality for most documents. The copy is scanned across the 8-1/2 inch dimension so that approximately 1,100 scan lines are required per page. It has also been determined that the resolution in the direction of fast scan should be of the order of 100 elements per inch so that as many as 850 brightness transitions could be resolved in one scan of the paper. These spatial resolution requirements, plus employing a simple modulation technique to transmit the data over a voice grade telephone line, more or less determine the data format for traditional facsimile machines such as those made by telautograph, Stewart Warner, and Xerox.

The modulation technique typically used is a simple technique where the photocell output directly modulates a carrier. The modulated carrier then is transmitted over a voice grade phone line. The time required to scan a line is usually of the order of a third of a second.

It is selected so that the highest bandwidth conditions (corresponding to 100 transitions per inch) can be supported by the bandwidth of the voice grade line.

The scanning mechanism is designed so that the time between the end of one scan line and the beginning of the next scan line is minimized. A reasonable ratio of scan duration to total duration is 90% (this quantity is often called scan efficiency). Therefore, the data format for a traditional facsimile machine is transitions occurring during a 300 ms scan interval and no transitions occurring during a 30 ms non-scan interval, followed again by a 300 ms scan interval, etc. This could last for 6 minutes for 11 inch copy. If the portion of the copy being scanned is white, there might be only two transitions per scan line, one as scan passes the left edge of the page and the other as the scanner leaves the right edge of the page. On the other extreme if the scanner is copying the white pages of a telephone directory, letters are being scanned at the rate of 20 per inch so that scanning a letter such as an "a" or "o" can give rise to transitions at the rate of 80 per inch, pushing the system near its limit. This corresponds to a few hundred transitions per line. The transition positions are retained in their analog form, i.e., they are not quantized in time.

3. Modern Facsimile Machines

The following discussion is centered around the Dacom DFC-10*. This is a commercially available facsimile unit that is probably representative of the state of the art for the next few years. This unit is also designed to transmit the data from an 8-1/2 x 11 inch page over a voice grade phone line. Some of its differences compared

---

* Described in the International Conference on Communications Record, June, 1970, AS 20-14 to 20-21.

to the traditional approach described above are:

(1) the position of the picture elements are quantized so that their position may be specified digitally;

(2) source encoding is employed so that, on the average, the number of bits transmitted over the channel may be 1/5 to 1/10 the number of picture elements scanned; and

(3) the output of the unit is synchronous-digital.

The source encoding used is a form of run length encoding. Described in its simplest form, run length encoding transmits a digital word describing the spacing between adjacent transitions. Thus, if the scanner is in a white area, no data is generated until a black picture element is found. Then a digital word is generated describing the spacing between the previous black-white transition and this white-black transition. Thus, the digital word also describes the length of the "run" of white elements. Hence, the name "run length encoding". The same procedure is employed for the black run lengths.

Dacom uses a digital word that is described as "adaptive". The digital word identifying run lengths is short (probably 2-4 bits) in areas of dense transitions. The digital word is longer (probably 6-12 bits) in areas of almost no transitions. This variable word length contributes to the overall efficiency of the source encoding. The essential point is that when the scanner notes a transition, the source encoder generates a word of 2 to 12 bits to describe the previous run length. Normally if no transition is observed by the scanner, the source encoder does not generate any data.*

* Sometimes there are exceptions to this in areas of extended run length. For example, if a white run of 900 bits is observed and the source encoded word can only accommodate a maximum run of 256 bits, the source encoder may generate widely spaced words indicating 256 elements, plus 256 elements plus 256 elements, plus 132 elements to indicate 900 elements.

The basic data format from the source encoder is no data during the non-active scan time and bursts of data of 2 to 12 bits during the active scan time. The total scan time per line in the Dacom unit may be 67 ms. or 33 ms. The ratio of the picture elements per scan line to the number of encoded bits per scan line is called the compression ratio and typically is of the order of 5 to 10 but probably could, for a short time, range from 0.5 to 25. Thus, looking at a worst case example for this type of system; assuming 33 ms. total scan time per line, 90% active scan to total scan time, 8-1/2 inch scan, 150 picture elements per inch and a compression ratio of .5, the source encoder could supply 2550 bits per 30 ms. If,on the other hand, we assume the other extreme of compression ratio of 25, the data rate would be 51 bits per 30 ms.

The Dacom unit is designed to supply a 2400 baud synchronous circuit. It is seen that the source encoder can supply data at both higher and lower instantaneous rates. To accommodate the synchronous transmission circuit, the facsimile unit takes one of two actions. If it is generating data too fast, which is the usual case, it stores a small amount of source encoded data in a buffer and momentarily stops the paper advance so that the source encoder receives no new input data. When the transmission system partially empties the buffer, the paper is again advanced. On the other hand, if this buffer is emptied because the compression ratio is very high, some "filler" data is inserted which is later ignored by the printer. Thus, if this unit is to be used with some form of packet switched transmission link, the precise behavior of this buffer must be considered and possibly altered. There is some possibility it can be used "as is" without causing the paper feed to be halted or filler bits to be added.

4. Future Trends

Future trends in facsimile machines include going to faster scan rates and more complex run length encoding techniques. Since transmission rates over voice grade phone lines is feasible at 4800 baud, it seems reasonable that the scanning rates should at least double, e.g., to 60 scans per second. Another implication of faster scan rates and buffering between the scanner and the transmission line is that scanning efficiencies need not approach 100% as they have in the past. It may be more economical to have scanning efficiencies of the order of 25%. Thus, while the Dacom DFC-10 may generate between (approximately) 2500 to 50 bits per scan line (with an average of 200?) during the active scan line time of 30 ms., a 60 scan/sec., 25% scan efficiency system will generate the same number of bits in an active scan line time of 4.17 ms. This is followed by an inactive time of 12.50 ms.

More advanced run length encoding techniques may attempt to obtain higher compression ratios at the expense of higher complexity. They may be implemented by reading a number of scan lines into the encoder at a time and then employing a combination of vertical and horizontal encoding. For example, assume: 60 lines scanned per second, 25% scanning efficiency (both as before) and three adjacent scan lines are encoded at a time. Thus, again, the information will be generated during an interval of 4.17 ms. (while every third line is being scanned). This data burst will occur every 3 lines scanned, i.e., every 50 ms. The total data in this 4.17 ms. interval will be approximately three times the numbers given in the preceding paragraph because it represents three lines.

5. Summary

This note cannot precisely define how a facsimile source encoder generates data. It is clear that source encoding is efficient enough to

warrant its use. It is also clear that the data rates generated from different documents will differ greatly, because that is the nature of efficient source encoders. The ratio of the maximum number of encoded bits in a scanned line compared to the minimum number may be as large as 50, while the same ratio on a page basis may be as large as 10, all due to different content of the document. The number of bits per transition and the gross grouping of these bits is subject to wide variation depending on the form of source encoding.